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II. Solution by G. W. GREENWOOD, M. A., Dunbar, Pa.

In the catenary, $y=c\sec\psi$, we have $s=c\tan\psi$ and $\rho=c\sec^2\psi$.

If a conic whose center is C osculates a curve at a point P, the center of curvature for the curve at that point being O, we have

$$\tan\phi=\tfrac{1}{3}.\frac{d\rho}{ds}, \text{ and } \frac{\cos\phi}{PC}=\frac{1}{\rho}-\frac{d\phi}{ds}, \text{ where } \phi=\angle OPC.$$

[Edwards' *Differential Calculus*, p. 356, 3d edition.]

$$\rho=c(1+\tan^2\psi)=c+\frac{s^2}{c},\quad \frac{d\rho}{ds}=2\tan\psi.$$

$$\therefore \tan\phi=\tfrac{2}{3}\tan\psi;\ (1+\tan^2\phi)d\phi=\tfrac{2}{3}(1+\tan^2\psi)d\psi.$$

$$\therefore \frac{\cos\phi}{PC}=\frac{1}{\rho}-\frac{d\phi}{d\psi}.\frac{1}{\rho}=\frac{1}{\rho}\left(1-\frac{6(1+\tan^2\psi)}{9+4\tan^2\psi}\right)=\frac{3-2\tan^2\psi}{\rho(9+4\tan^2\psi}=0,$$

when $y=c\sec\psi=\dfrac{c\sqrt{10}}{2}$.

Hence (since $\cos\phi\neq0$), PC is infinite, and the conic is a parabola.

This question was set at Oxford in 1889.

Also solved by G. B. M. Zerr.

MECHANICS.

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200. Proposed by C. N. SCHMALL, 89 Columbia Street, New York City.

An elastic string whose weight is W is laid over the top of an inclined plane so as to remain at rest. Determine how much the string will be elongated, knowing, M=modulus of elasticity, L=normal length of string, and ϕ=inclination of the plane.

Solution by G. B. M. ZERR, A. M., Ph. D., Parsons, W. Va.

Let M=mass of unit length of the unstretched string. The equation of equilibrium is $dT+Mg\sin\varphi ds=0$. But $MgL=W$.

$\therefore T+\dfrac{W\sin\varphi s}{L}$=constant. Now when $s=0$, $T=W\sin\varphi$.

$$\therefore T=W\sin\varphi(1-\frac{s}{L}).\quad \text{Also } dl=(1+\frac{T}{M})ds=[1+W\sin\varphi(\frac{1}{M}-\frac{s}{LM})]ds.$$

$$l=\int_0^L[1+W\sin\varphi(\frac{1}{M}-\frac{s}{LM})]ds=L[1+W\sin\varphi(\frac{1}{M}-\frac{1}{2M})]$$

$$=L[1+\frac{W\sin\varphi}{2M}]. \quad \therefore \frac{WL\sin\varphi}{2M} \text{ is the elongation.}$$

Also solved by the Proposer.

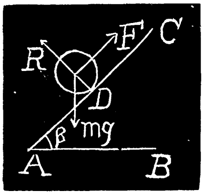
201. Proposed by G. B. M. ZERR, Ph. D., Parsons, W. Va.

ABC is an inclined plane, perfectly rough, length $AC=l$. The time for a sphere to roll down when *AB* is base is to the time for a cylinder to roll down when *BC* is base as *m* is to *n*. Find *AB* and *BC*.

Solution by J. SCHEFFER, A. M., Kee Mar College, Hagerstown, Md.

Let *O* be the center of any rolling body of mass *m*; then the three forces that will act on it are its weight *mg* vertically downward, the resistance *R* on the inclined plane *AC*, and the friction *F* acting up the plane.

Denoting *CD* by *s*, we have therefore $m(\partial^2 s/dt^2)=mg\sin\beta-F$; and if we denote by θ the angular velocity, reducing the mass to the center *O*, we have $m\rho^2(\partial^2\theta/\partial t^2)=Fr$, r being equal to *DO*, and ρ radius of gyration. Since there is no sliding, the plane being perfectly rough, we have $s=r\theta$. Eliminating *F*, we have $\partial^2 s/dt^2=[r^2/(r^2+\rho^2)]g\sin\beta$, and integrating



$$s=\frac{r^2}{r^2+\rho^2}g\sin\beta\, t^2.$$

For the sphere $\rho^2=\frac{2}{5}r^2$, and for the cylinder $\rho^2=\frac{1}{2}r^2$; therefore, by the condition of the problem, for the sphere

$$l=\frac{r^2}{r^2+\frac{2}{5}r^2}g\,.\frac{BC}{l}t^2, \text{ whence } t^2=\frac{14l^2}{5g.\overline{BC}},$$

and for the cylinder, $l=\dfrac{r^2}{r^2+\frac{1}{2}r^2}g\,.\dfrac{AB}{l}t^2$, whence $t^2=\dfrac{3l^2}{g.\overline{AB}}$; $\therefore \dfrac{14}{5\overline{BC}}:\dfrac{3}{\overline{AB}}=m^2$

$:n^2$, and combining this with $\overline{AB}^2+\overline{CB}^2=l^2$, we get

$$AB=\frac{14n^2l}{\sqrt{(225m^4+196n^4)}}, \quad CB=\frac{15m^2l}{\sqrt{(225m^4+196n^4)}}.$$

Also solved by J. Edward Sanders, and the Proposer.

AVERAGE AND PROBABILITY.

185. Proposed by R. D. CARMICHAEL, Anniston, Ala.

If a line *l* is divided into *n* parts by $n-1$ points taken at random on it, what is the mean value of the *p*th power of one of the parts taken at random?